Revisiting OCN and the Hinge for Seasonal Prediction and Interannual Signal Separation

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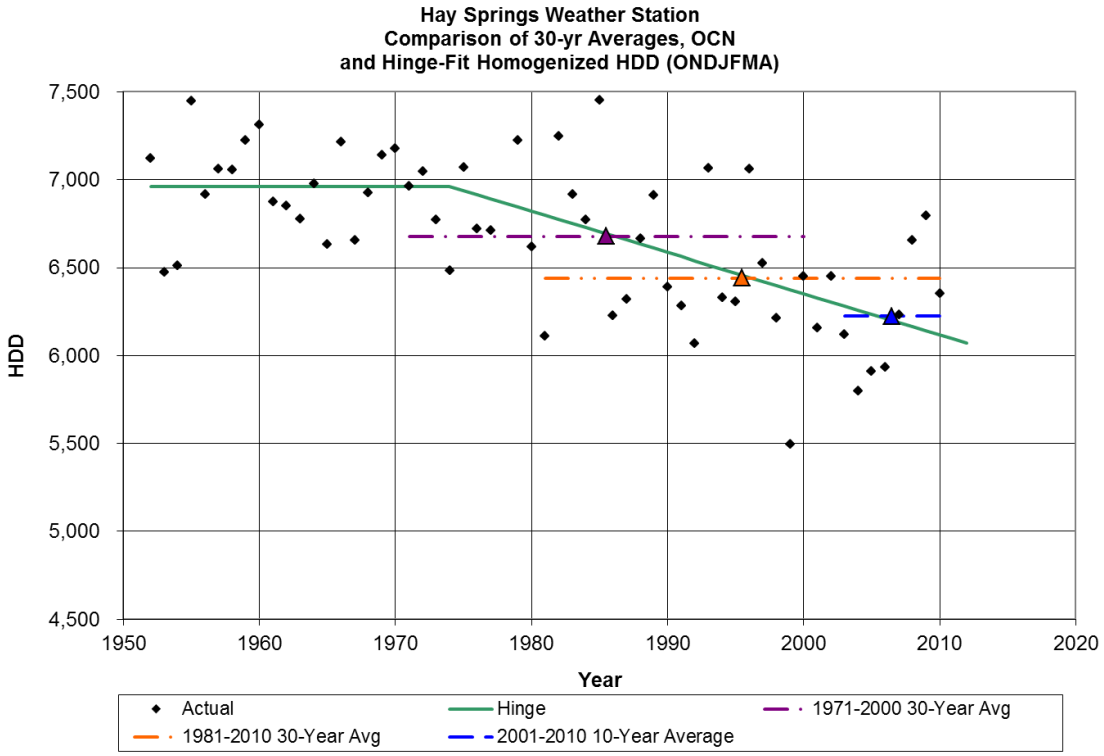
Outline

- Introduction and motivation
  - Two challenges of the warming climate:
    - Estimating normals as "expected values" rather than as retrospective references; forecasting next year
    - Tracking the normal history; signal separation
- Best simple methods (for forecasting next year)and their merits
  - 15 year OCN
  - 1975 hinge model
  - A note about other smoothers
- Independent tests
  - Validation of hinge model design
  - Relative performance on different surface data sets
- Conclusions and Recommendations

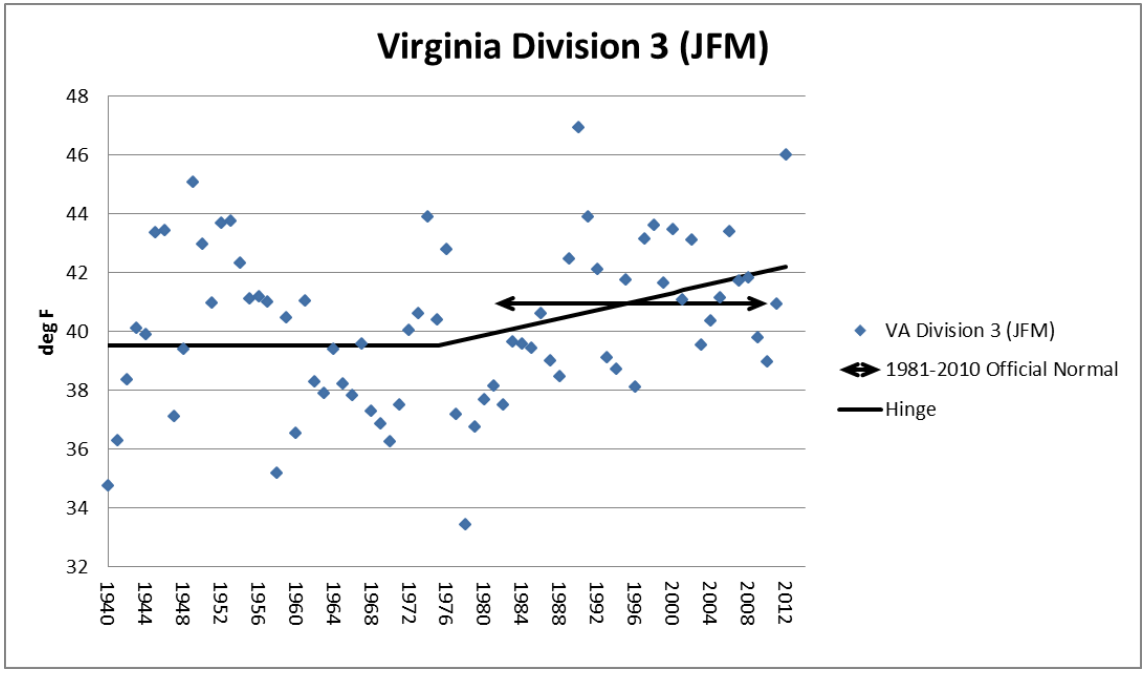
Introduction and Motivation

- Climate change is underway so climate normals are non-stationary
- For U.S. surface temperatures, non-stationarity is notable and widespread in all seasons



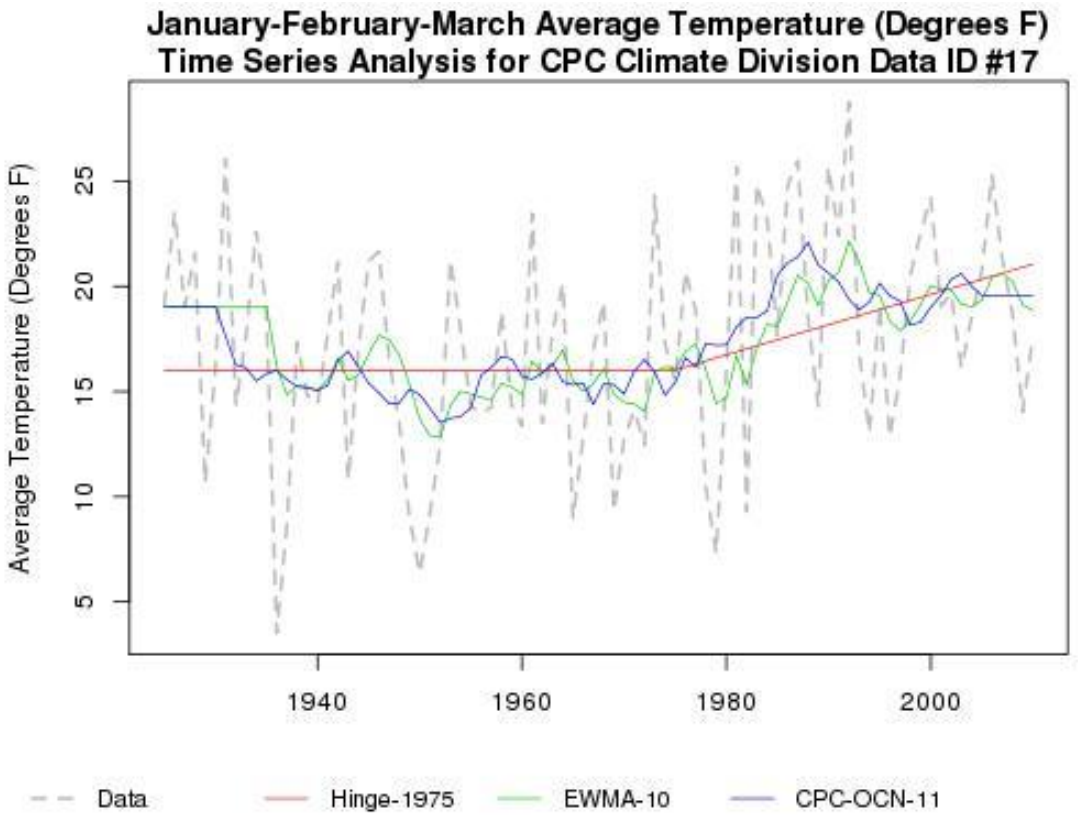
Introduction and Motivation

- Estimating current temperature normals is important, but so is tracking their changes (*i.e. separate climate change signal from climate noise*)
  - Plotted examples are called 1975 hinges
- The objective of tracking is the best, most relevant estimates of:
  - Rates of warming
  - Variability (climate noise)
  - Current probabilities and conditional probabilities



Introduction and Motivation

- To calculate composites, histograms, and estimates of probability distributions and probabilities relevant to the current climate:
  - Track the non-stationary normal completely as simply and smoothly as reasonable
  - Assume that, at least to 1st order, climate noise has been independent of climate change
  - Compute residuals to the tracked normal
  - Recenter residuals to the current normal
- If you don't take these or appropriate alternative steps for temperature or temperature-related variables, in most places and most times of the year:
  - Your results will be erroneously cold-biased
  - You will have screwed up



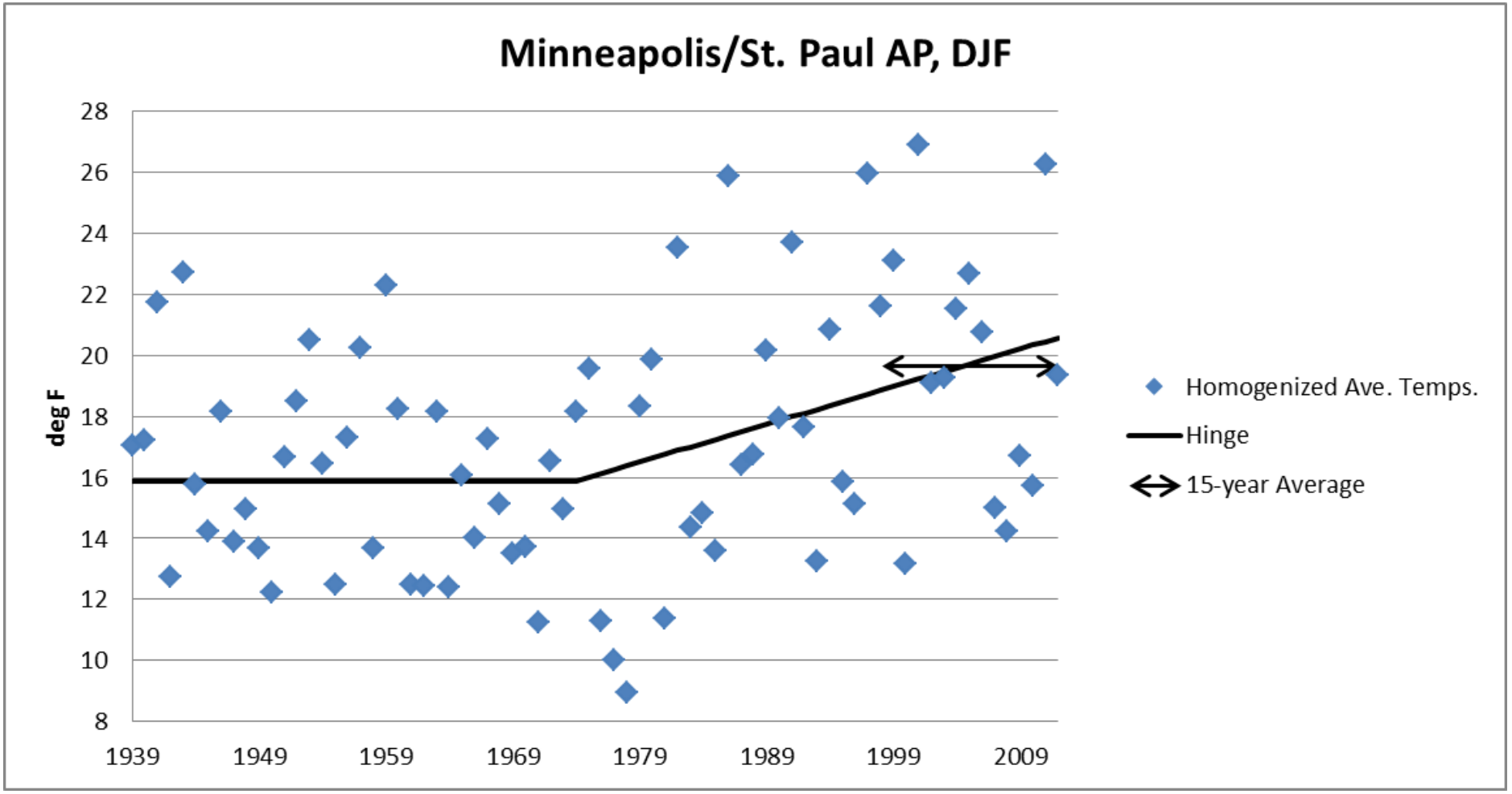
Best available simple methods for 9-month lead seasonal temperature forecasts

- Based on Wilks' (W13; JCAM, 2013) and Wilks and Livezey (WL13; JCAM, 2013)

- Fixed 15 year Optimum Climate Normal (OCN; CPC15)
  - Best overall tradeoff between bias error (increases with averaging period) and sampling error (decreases with averaging period)

- 1975 hinge (Livezey et al., 2007; L7)
  - Fitted change-point variant degrades performance
  - Fitted pre-1975 slope has negligible effect on performance

Examples of best available simple methods



Merits and demerits of CPC15 and the hinge

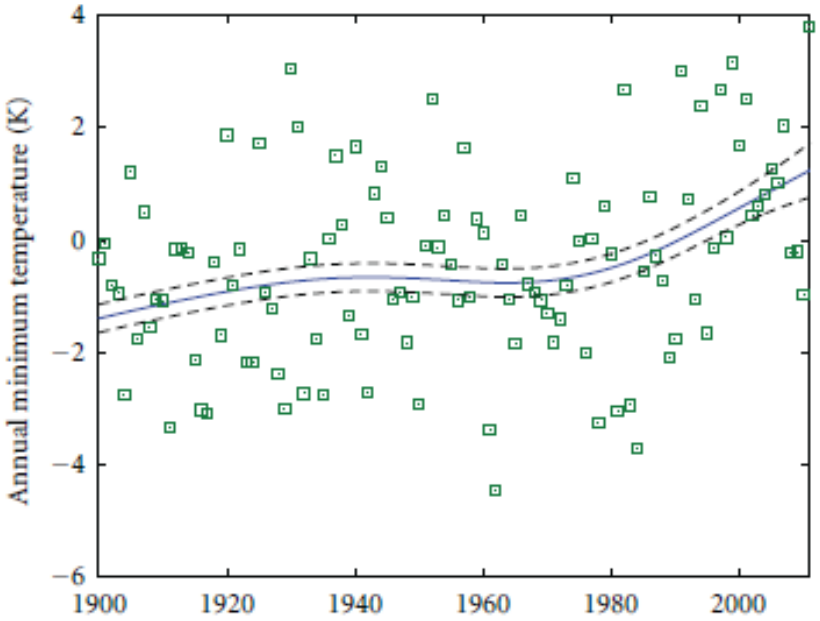


FIGURE 4: Annual minimum temperature anomaly (relative to the 1976–2005 mean) averaged across the coterminous USA, along with a fitted trend curve. Dashed curves show a 1-σ uncertainty envelope for the trend.

- Krakuaer (Advances in Meteorology, 2012)

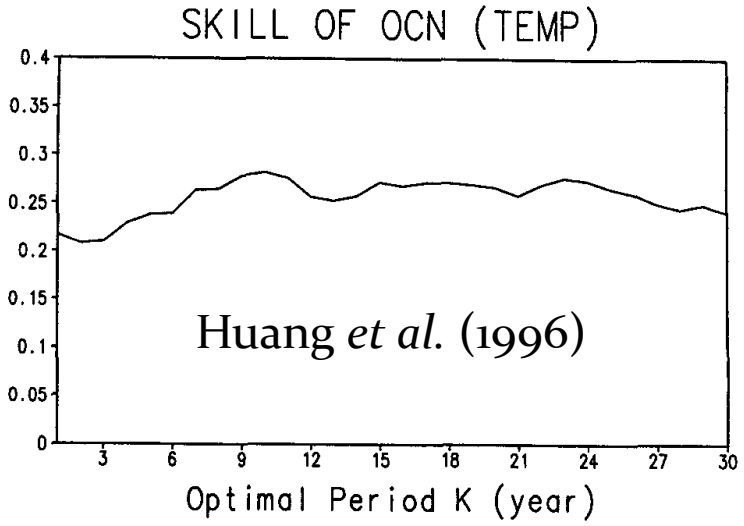
- OCNs are the least stable and *can't be used to track the full record smoothly and without compromises*, but are expected to have small bias and squared errors when warming is moderate
- 1975 hinge has all desirable attributes; parsimonious, well-supported model of climate change
- Some time series smoothers have all desirable attributes, but are more arbitrary and complicated than the hinge; best just produce smoothed out hinges

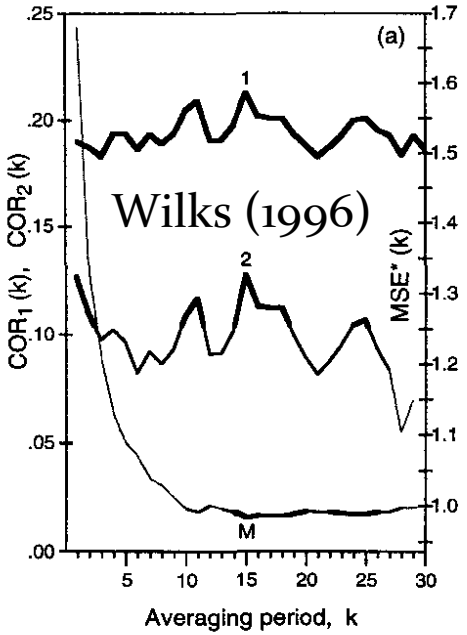
Independent Tests of OCNs and Hinges

- WL13 tested CPC's OCNs and L7 and other hinges over **1994-2012** on:
  - **Megadivisional data**
    - To repeat W13's results; CPC15 overwhelmingly best in error reduction, 1975 hinge distant second
  - **Station data with TOB corrections** from the 1218 station USHCN
    - Hinge-based methods improved relative to OCNs
  - **Fully-homogenized station data** from the 1218 station USHCN
    - 15-year OCN remains best overall, but now 1975 hinge is close second
    - For 2006-2012 15-year OCNs and 1975 hinges were each best 5/12 seasons-regions considered, but 1975 hinges had the best overall biases in 6/12 cases and 2nd in another (no other method had more than 2)
  - Any advantages of the 15-year OCN over the 1975 hinge (and the 10-year OCN) are dominantly a consequence of the unusually severe cold seasons for 2007/08 through 2010/11 (especially in the West)

Why is 15-years the best overall OCN for the US when 10-years was apparently the best through 1993?

- Actually Wilks (1996; *J. Climate*) concluded otherwise.
- Huang *et al.* (1996; *J. Climate*) substantially underweighted the contribution of the western third of the US
- The divisional data used by both studies was replete with non-climatic in homogeneities subsequently removed by NCDC





Conclusions and Discussion

- Warming is so ubiquitous that relevant current normals are dominantly best estimated with alternatives to 30-year averages *except under extreme departures from this warming*:
  - We don't know the exceptions in advance
  - 15-year averages have been the most resilient for all data sets, the 1975 hinges otherwise
  - The 1975 hinges are the best choice if bias reduction is more important than reduction of variance with respect to 30-year averages

- For signal separation :
  - The changing climate needs to be tracked smoothly and reasonably and the preferred methodology is the 1975 hinge
  - When possible, tracking and distribution estimation should be based on homogenized records

- If uniformity is not a requirement, the best methodology, whether the 15-year OCN, the 1975 hinge or a hybrid approach, depends on your objectives

Recommendation

- CPC should replace the 10-(11-?)year OCN for forecasting with a 15-year version, the hinge, or a hybrid approach

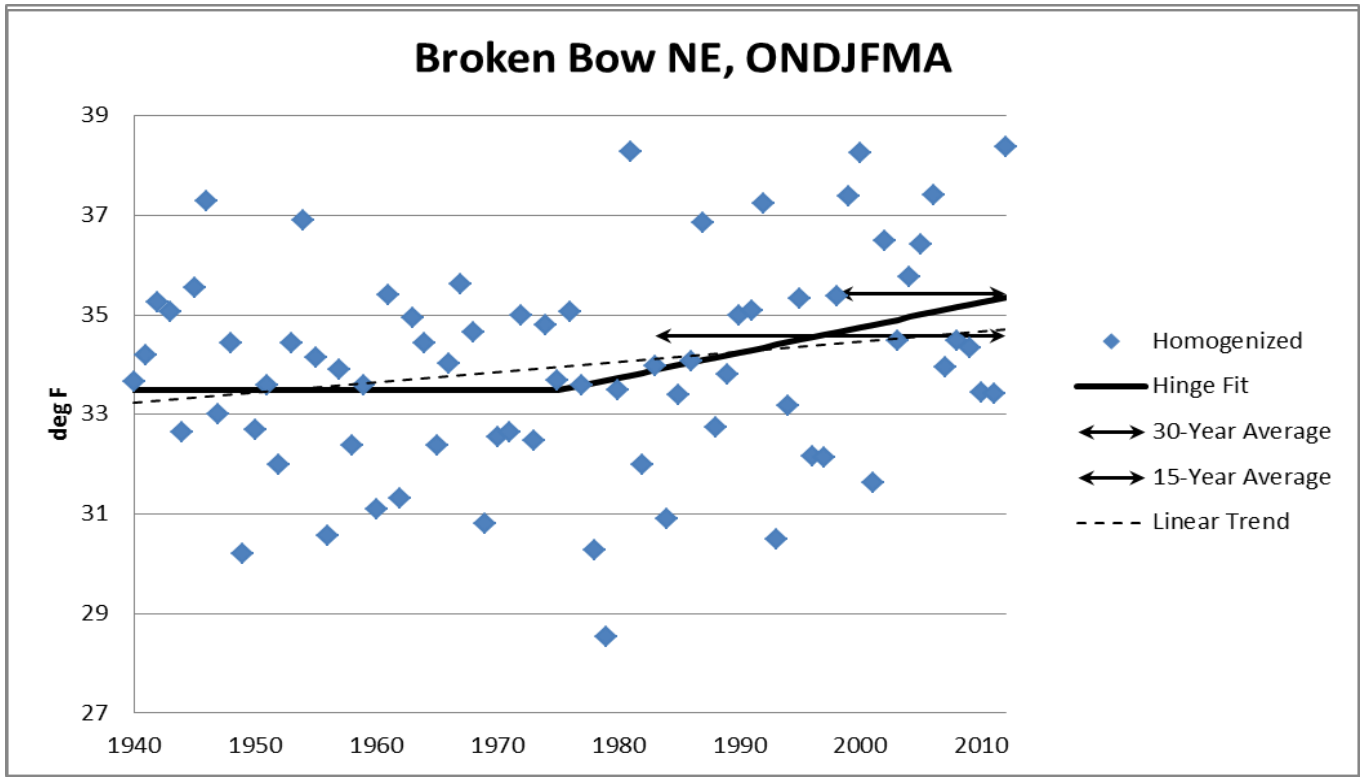
Supplemental Slides

Is use of homogenized data necessary and important?

- NCDC provides easy public access to homogenized station records for the 1218 UCHCN along with corresponding raw and time-of-obs (TOB) corrected series.
- NWS (CSD)/NCDC provides field office access to homogenized records at least at 4000 additional stations.
- NCDC is addressing requirements for homogenized records for both monthly mean divisional data and daily station data.
- Are CPC in-house records as free of inhomogeneities?
- In this context CPC and NCDC goals are compatible, so shouldn't leveraged data sets be consistent?

Is use of homogenized data necessary and important?

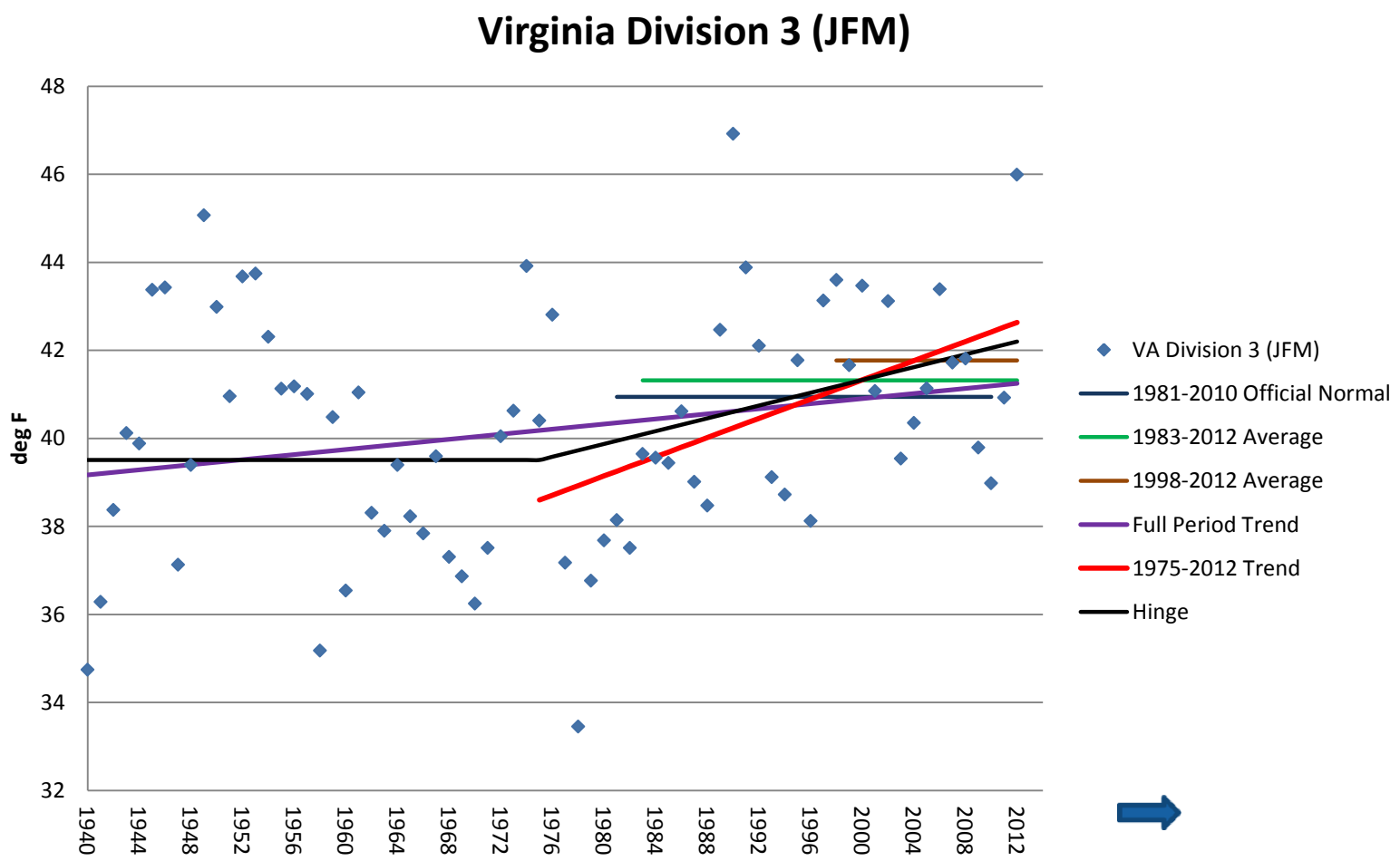
- Emphatically yes if your goals are best estimates of current climate, warming trends, probabilities and conditional probabilities!



Methods and their expected merits (demerits)

- Time averages:
  - 30-years
  - Less than 30-years
  - Optimum Climate Normals (OCN) minimize sum of bias error (increases with averaging period) and sampling error (decreases with averaging period)
    - Fixed 10- or 15 years (CPC_{10} & CPC_{15})
    - Tailored to case (location/season):
      - Best performer over dependent period (OCN)
      - Optimize based on trend estimates

Methods and their expected merits (demerits)



Methods and their expected merits (demerits)

- Trend-based methods
  - Full-period trend
  - Post-1975 trend
  - 1975 hinge (Livezey et al., 2007; L7) →
  - Estimated change-point and 2-phase hinges (3 variants)
    - Fit change point case by case (C Est)
    - Fit 1940-1975 slope case by case (Two-Phase C=1975)
    - Fit both of the above (Two-Phase C Est) →
- Various time series smoothers (autoregressive or spline methods)

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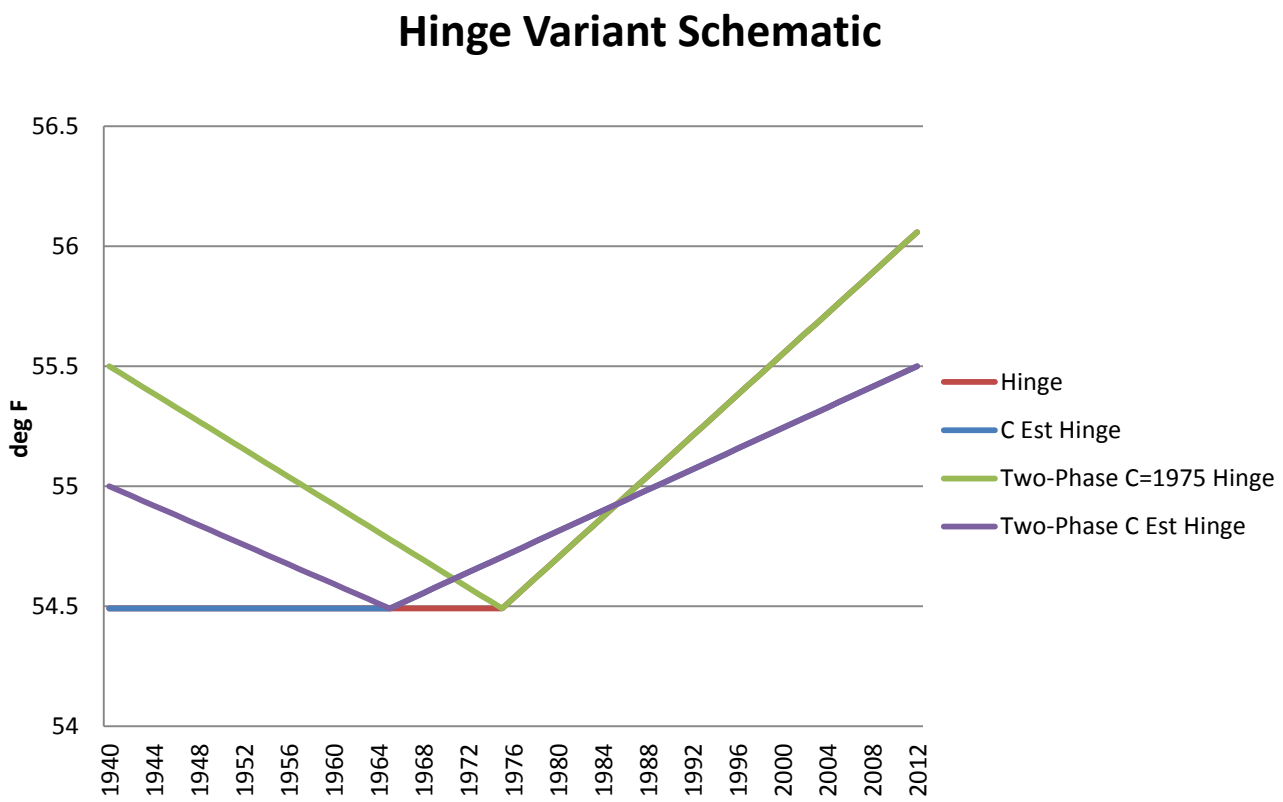
Methods and their expected merits (demerits)



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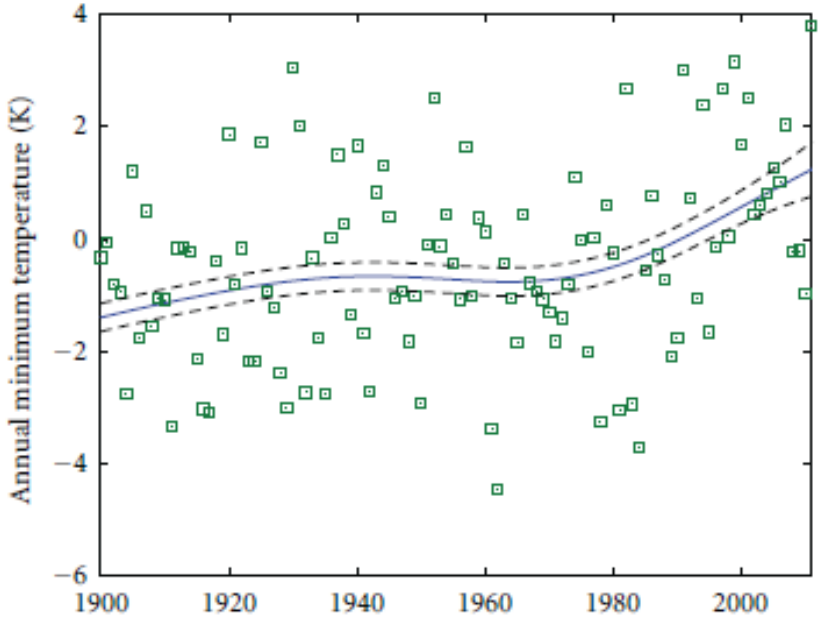

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- OCNs are the least stable and *can't be used to track the full record smoothly and without compromises*, but are expected to have small bias and squared errors when warming is moderate
- Post-1975 trend still unstable, but less so, with similar errors, but *cannot track the full record*
- Full-period trend is very stable and can track the full record smoothly *but not realistically*, and has larger biases and squared errors
- 1975 hinges (1- and 2-phase) have all desirable attributes; parsimonious, well-supported model of climate change
- Time series smoothers are the most arbitrary and require more compromises; generally just produce smoothed out hinges

Conclusions and Discussion

- WL13 Hybrid
- 15-year average used unless 1975 hinge slope exceeds significance threshold
- Horizontal axis shows increasing use of hinge from right to left
- Using the 1975 hinge in 14% of all cases reduces the average bias by 1/3 but increases the RMSE by less than 1%